



BaBar Results on the $D_s \pi$ System

R. Cahn

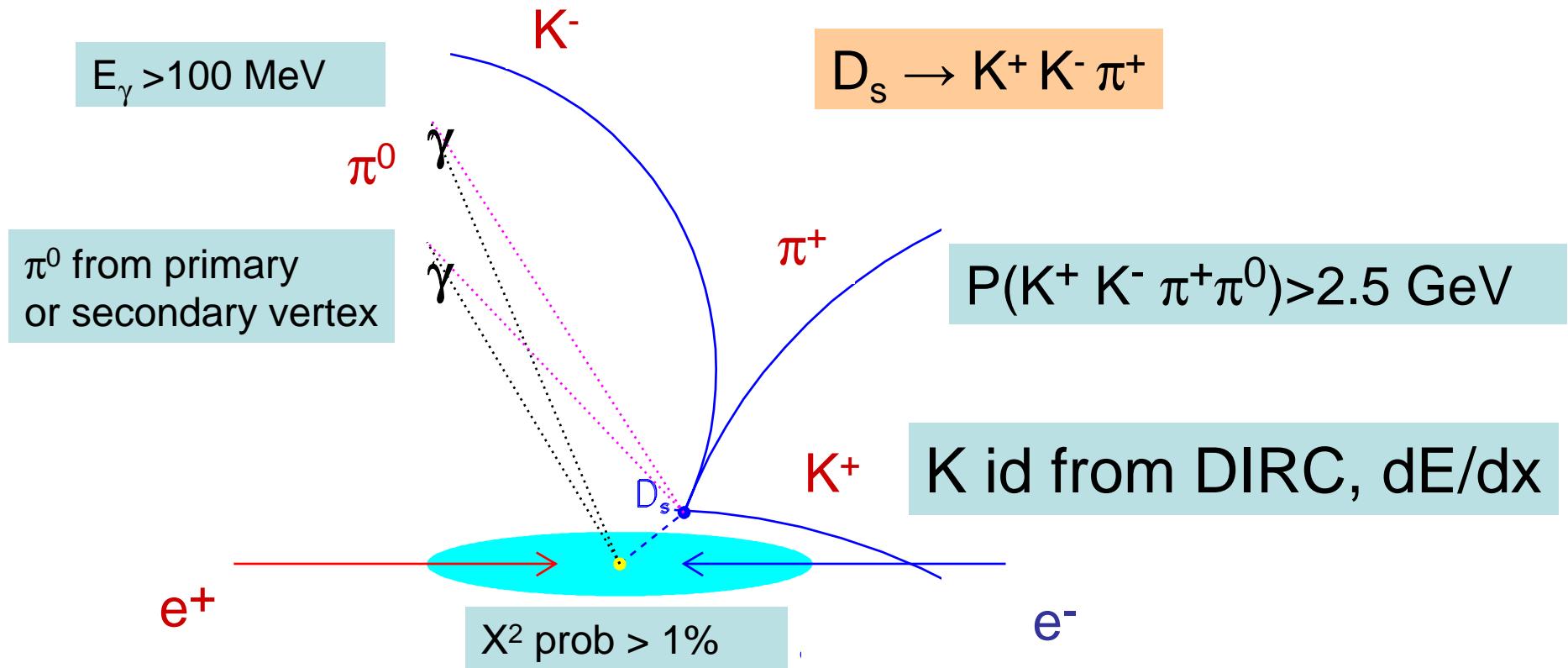
LBNL

Hadron 2003

Aschaffenburg, Sept. 4, 2003

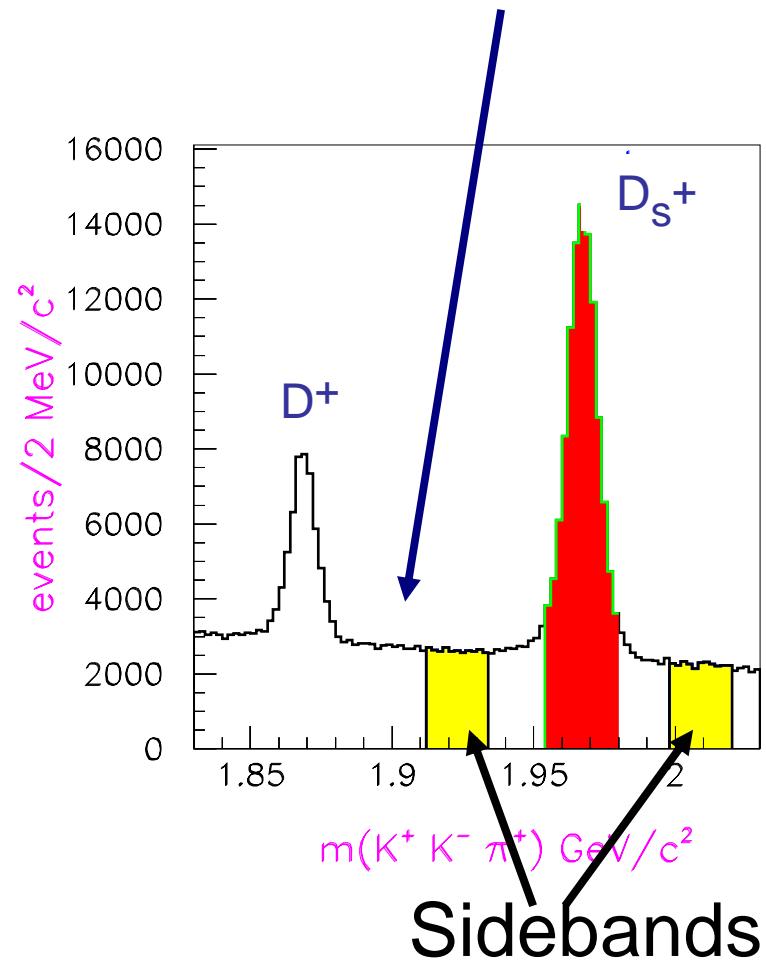


Event Selection





Suppress background



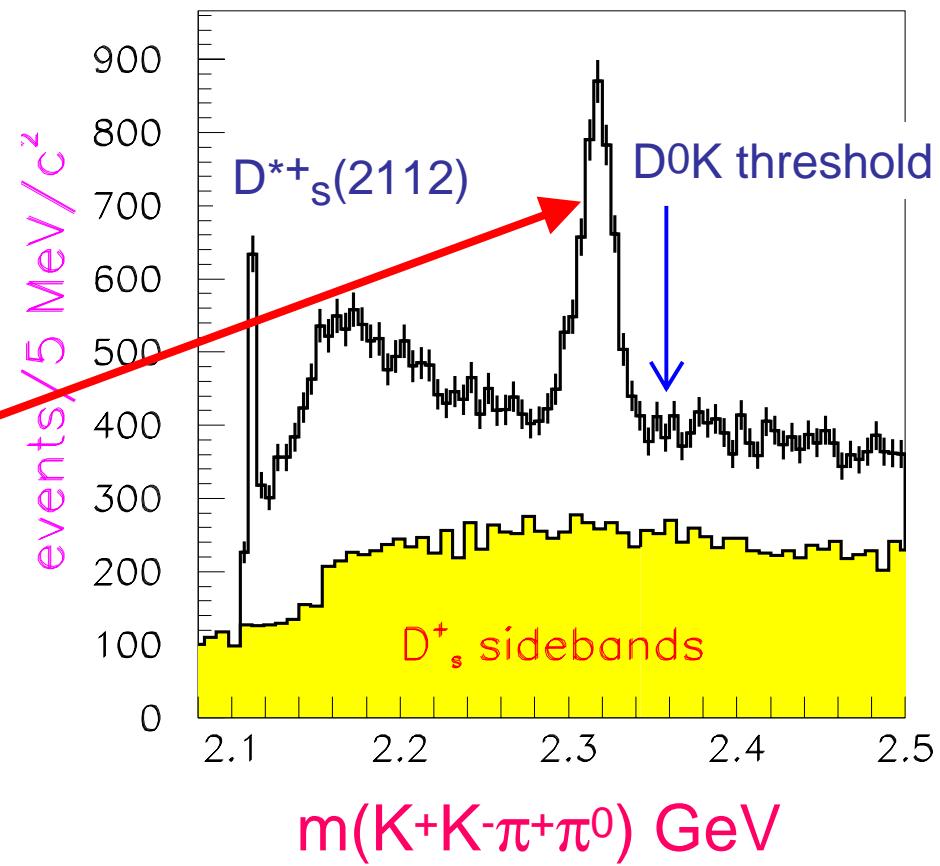
Require K^*K or $\phi\pi$

Cut on decay angle:
 $|\cos \theta| > 0.5$



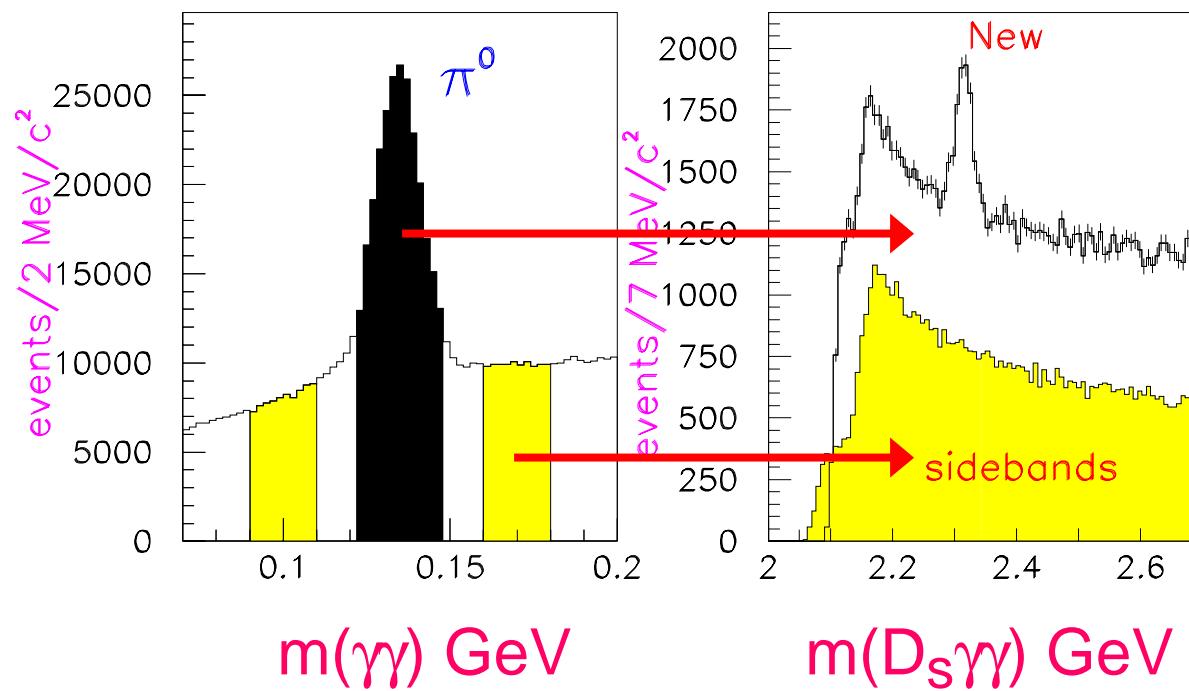
Add π^0 to D_s :

$D_{SJ}^*(2317)$





Not there for fake π^0





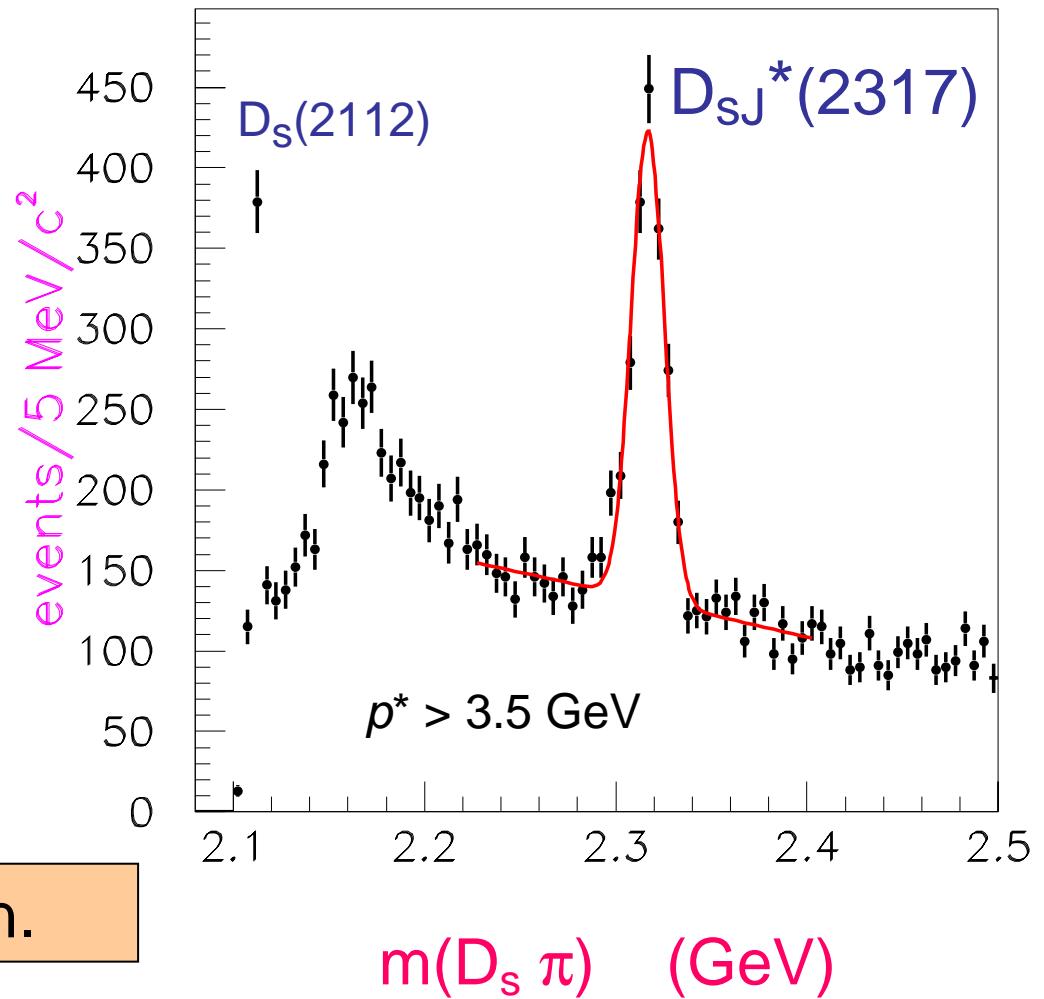
Fit to mass, width:

$$M = 2316.8 \pm 0.4 \text{ MeV}$$

$$\sigma = 8.6 \pm 0.4 \text{ MeV}$$

(Statistical errors only)

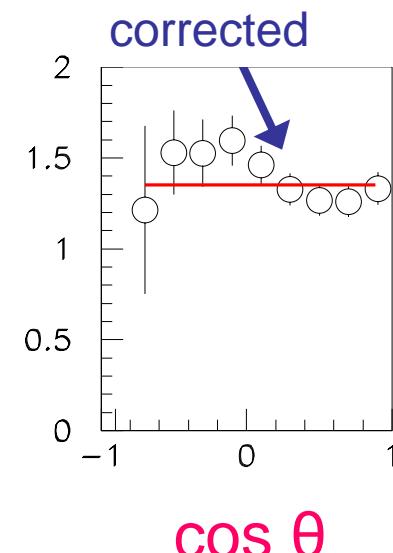
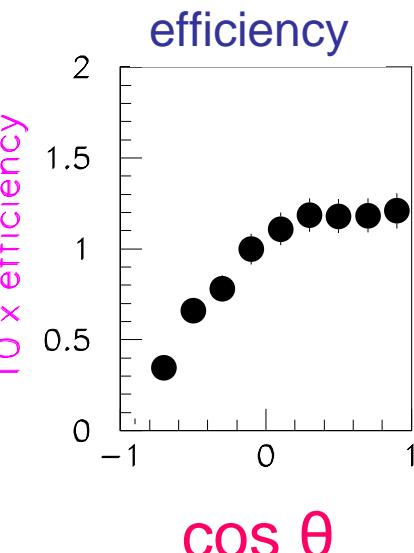
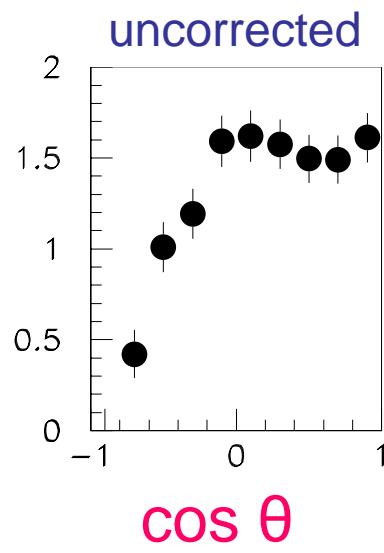
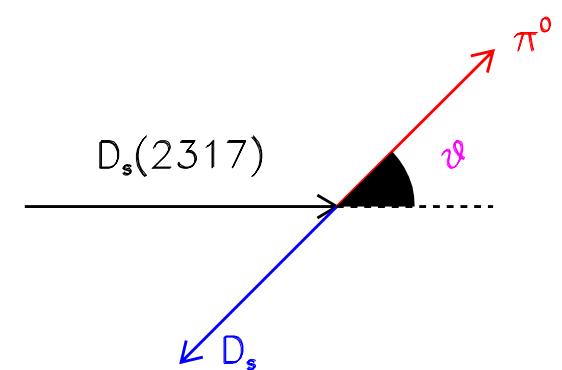
σ consistent with resolution.





Angular distribution featureless

$D_{sJ}(2317)$ spinless or unaligned





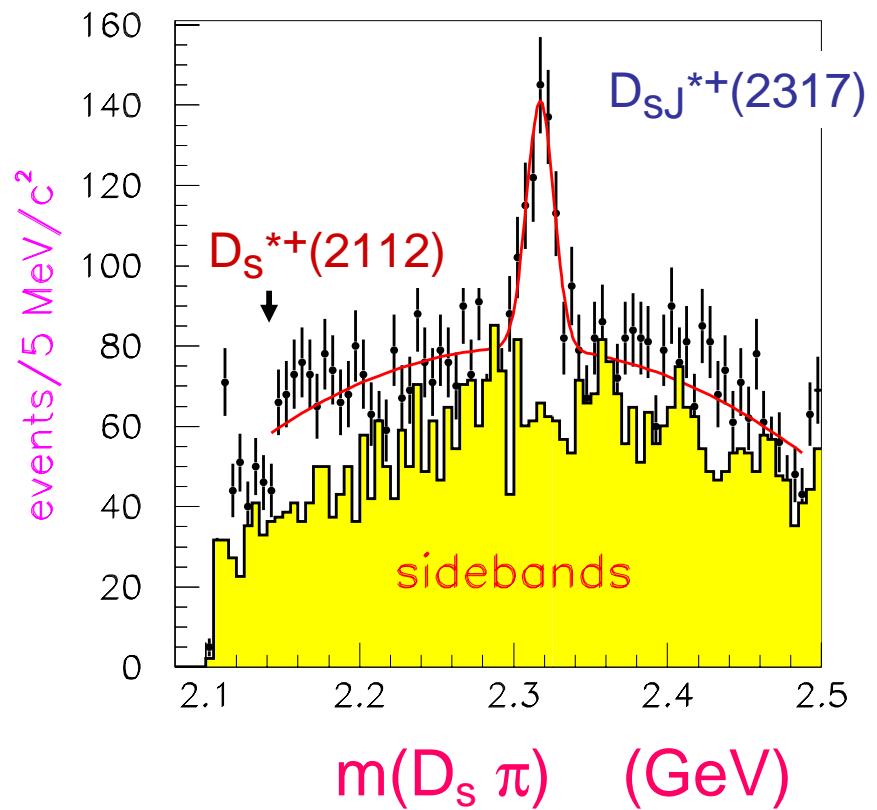
Consistent results in second mode:

$$D_s \rightarrow K^+ K^- \pi^+ \pi^0$$

$M = 2317.6 \pm 1.3 \text{ MeV}$

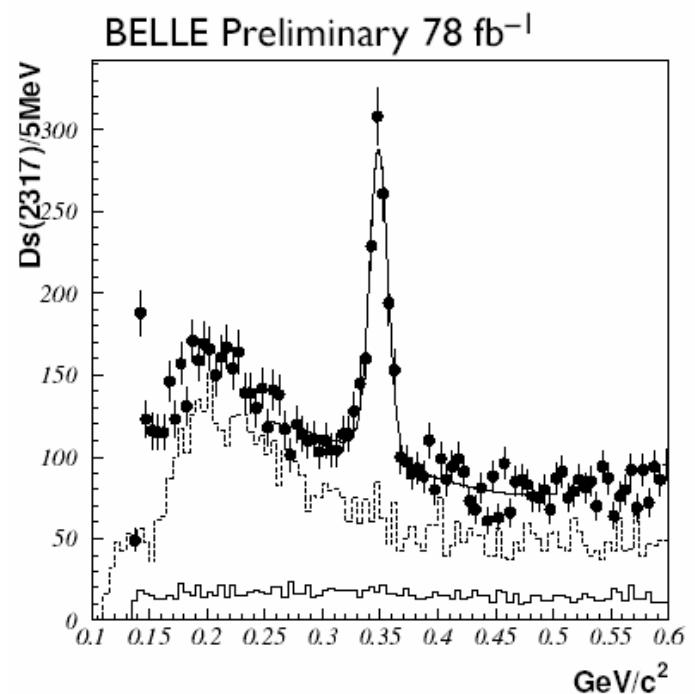
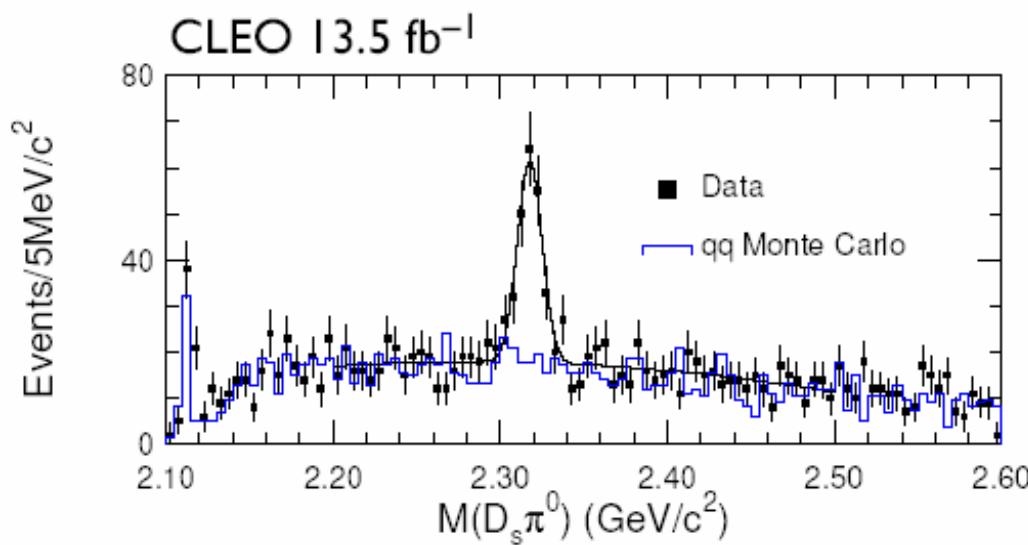
$\sigma = 8.8 \pm 1.1 \text{ MeV}$

(Statistical errors only)





State Confirmed by CLEO and Belle





$D_s(2317)$: Immediate conclusions

- $D_s \pi^0$ has charm, strangeness, isospin.
- If initial state is $c\bar{s}$,
strong isospin-violating decay.
- Explains narrowness.
- Must be natural spin-parity.

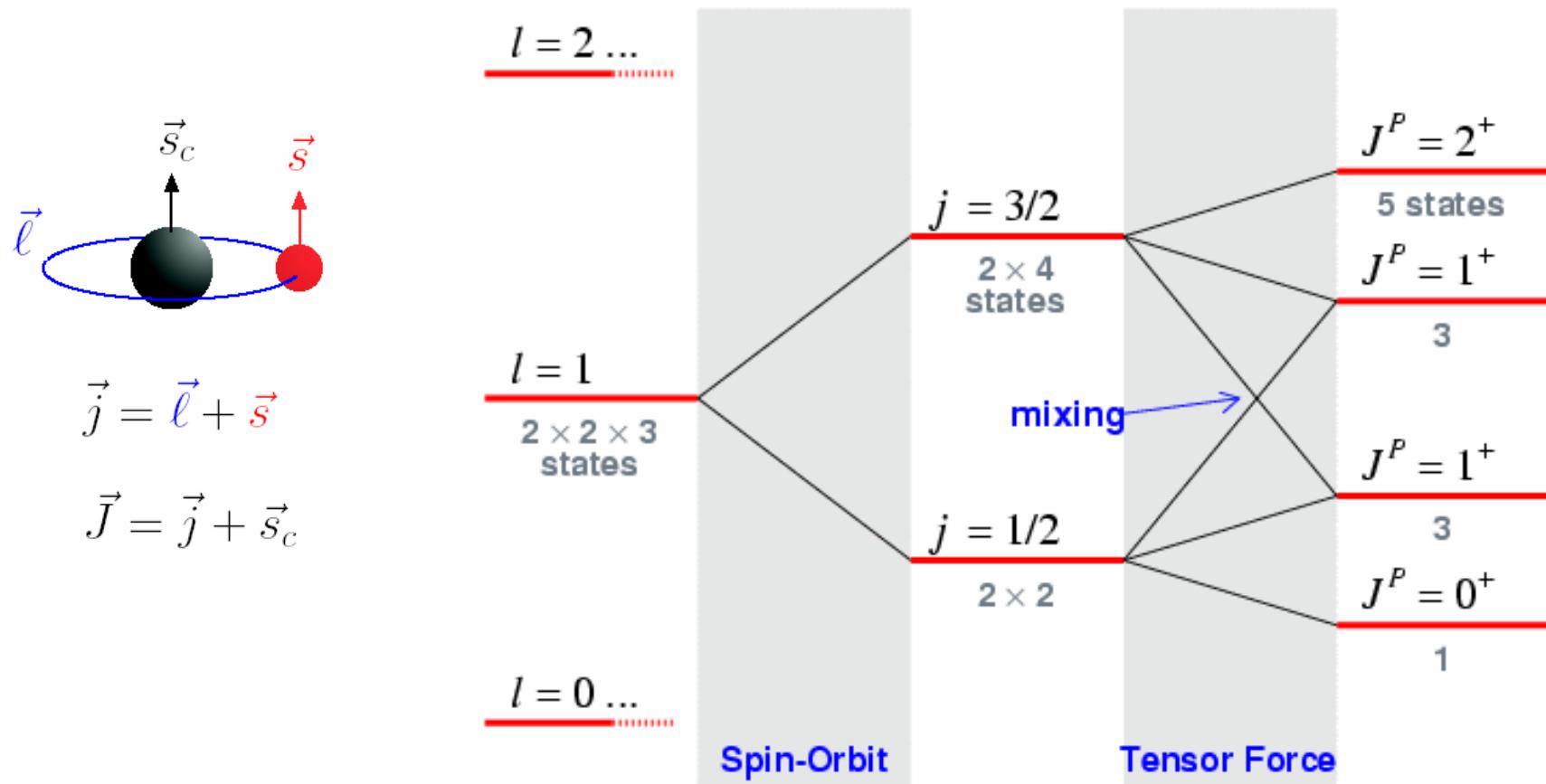


Deja Vu

- Heavy-quark light-quark = the hydrogen atom!
 - DeRujula, Georgi, Glashow 1975
- Heavy quark's spin doesn't matter much
- Add light quark's spin \mathbf{s} , orbital / angular momentum: $\mathbf{j} = \mathbf{l} + \mathbf{s}$
- \mathbf{j} nearly conserved
- $\mathbf{J} = \mathbf{j} + \mathbf{s}'$ really conserved

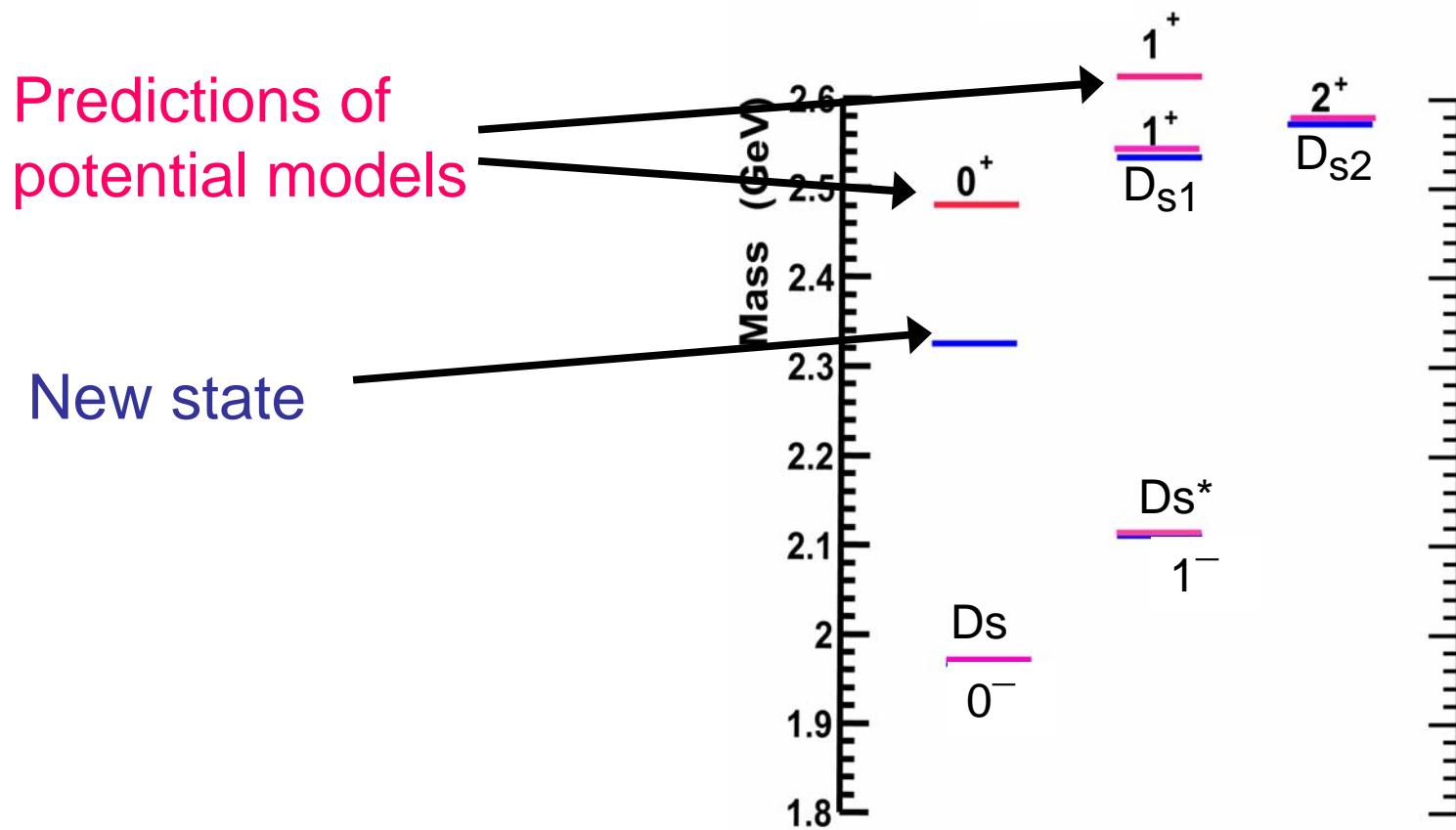


Interactions split energy levels of p-wave states





New State 170 MeV Below Potential Model Predictions





Looking in other channels

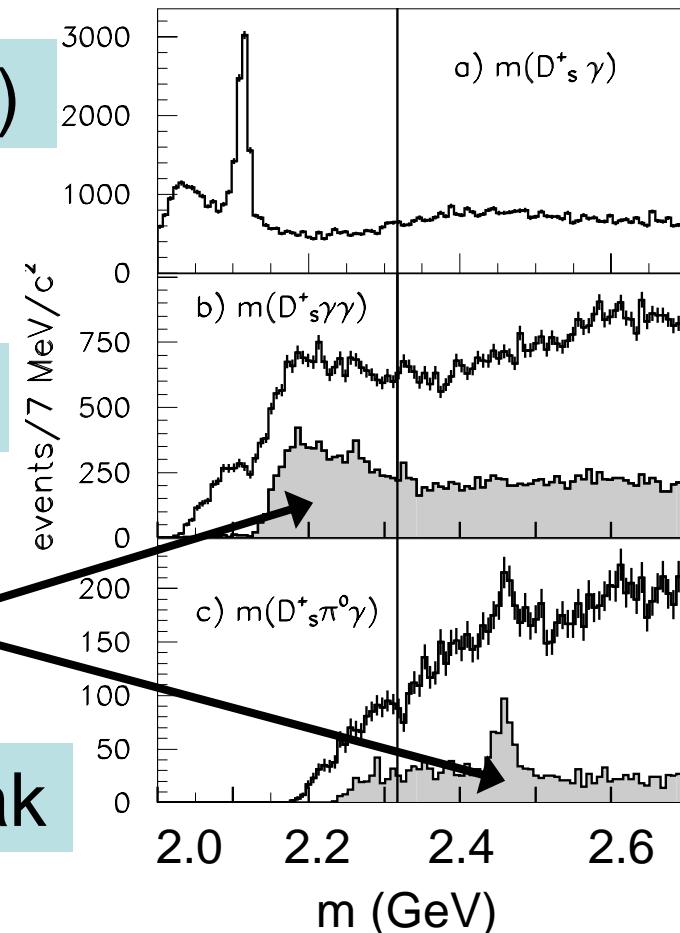
BaBar PRL90,242001(2003)

$D_s \gamma$: only the $D_s(2112)$

$D_s \gamma\gamma$: nothing

Events with a $D_s \gamma = D_s^*$

$D_s \pi^0 \gamma$: some sort of peak

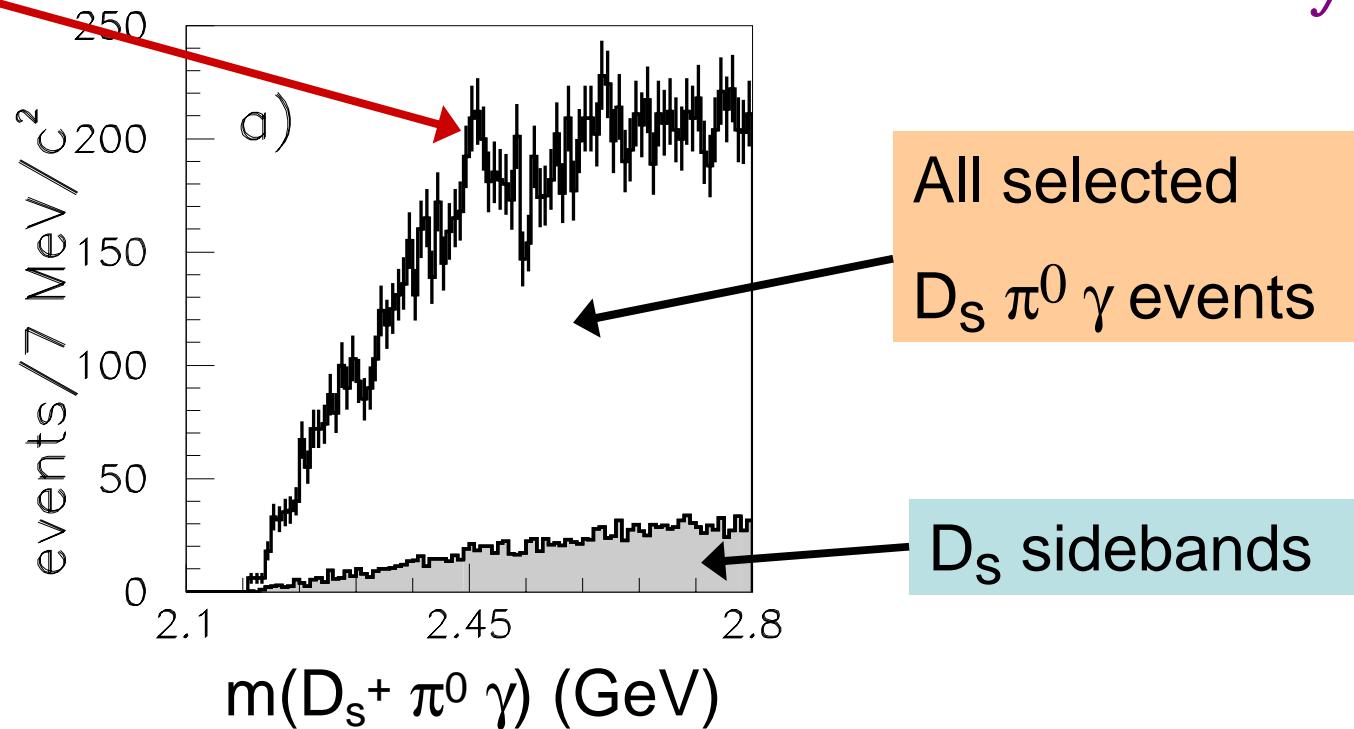




Is peak a real effect?

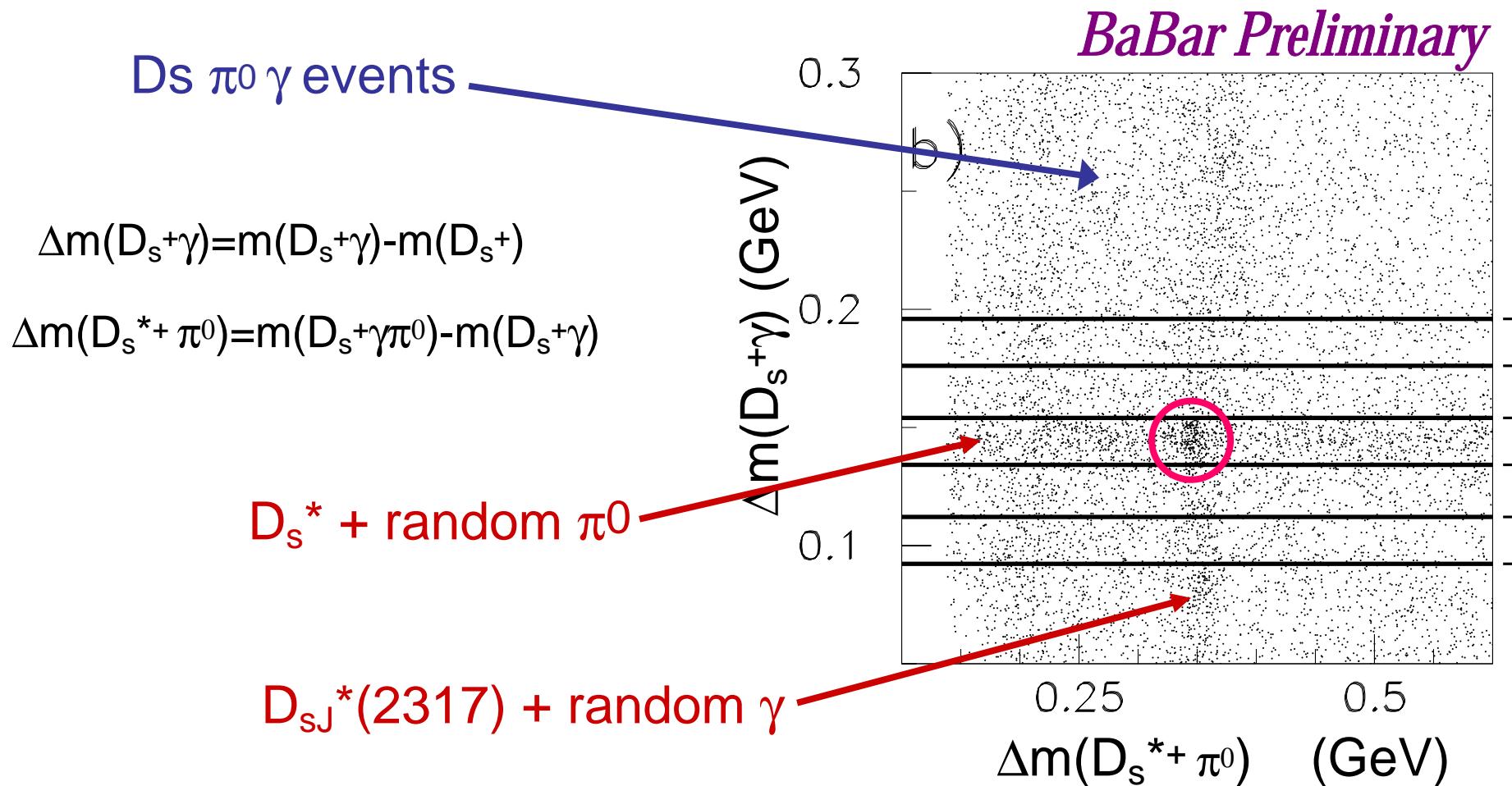
Potential peak

BaBar Preliminary





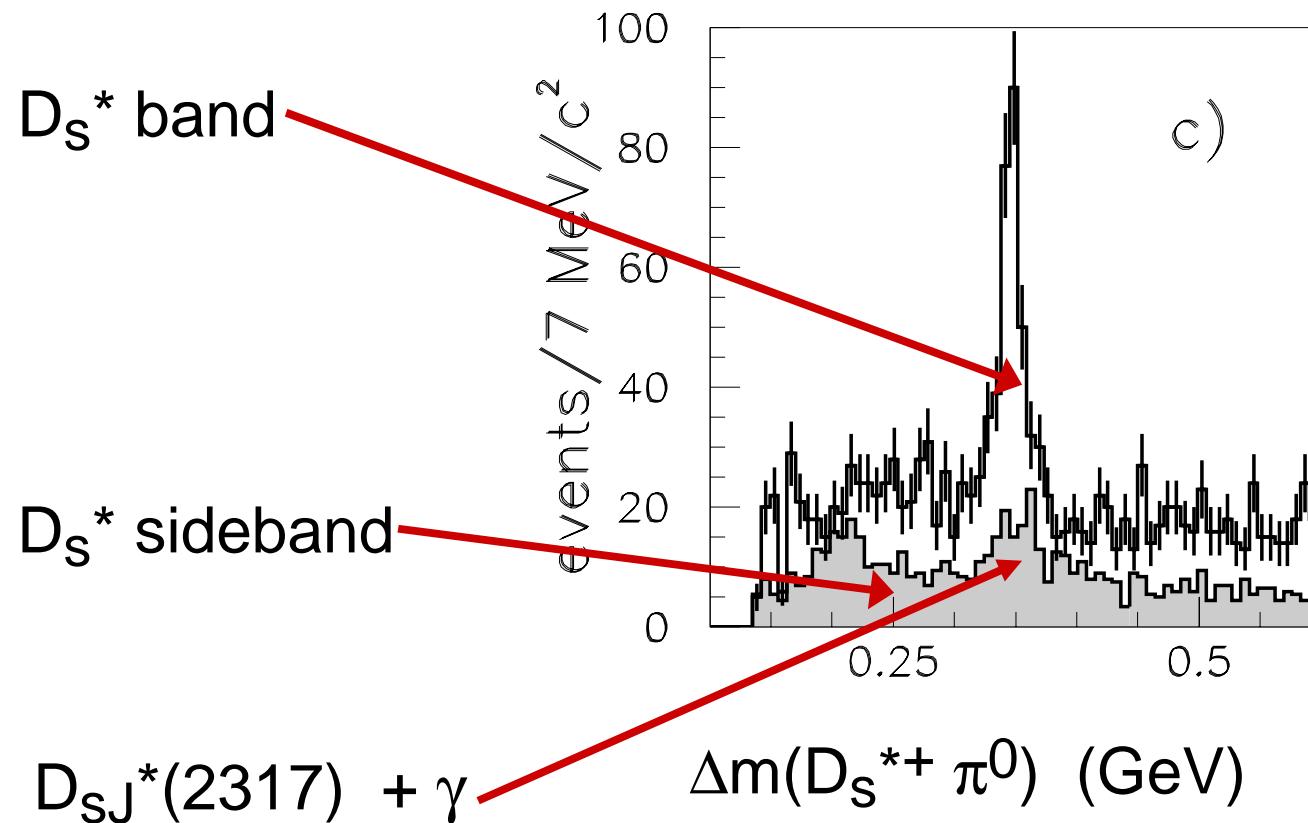
Real effect or overlapping bands?





Background small, peaks higher than signal

BaBar Preliminary



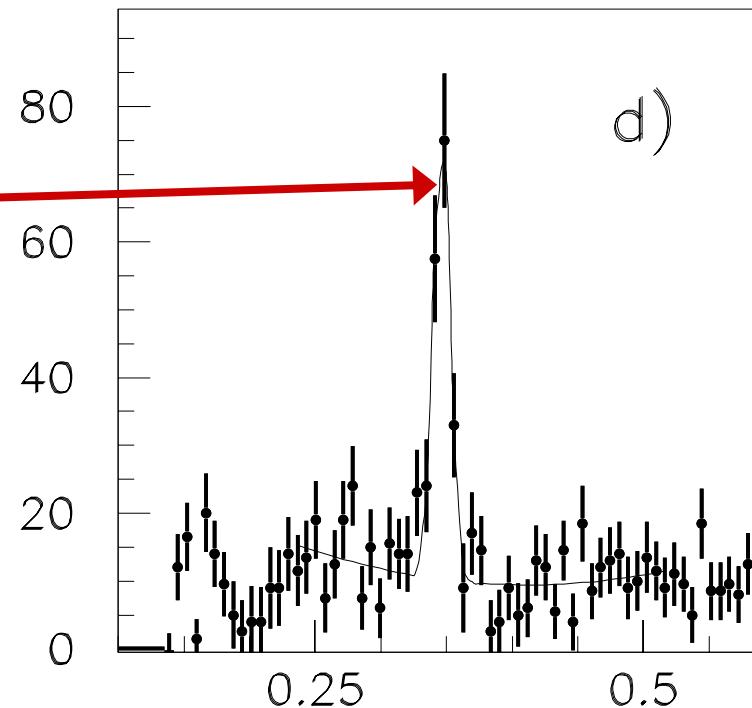


Sideband-Subtracted Spectrum

BaBar Preliminary

$\Delta m = 346.2 \pm 0.9 \text{ MeV}$

(statistical error only)



$\Delta m(D_s^{*+} \pi^0) \text{ (GeV)}$



What is decay path for DsJ(2458)?

- If $D_{SJ}(2458) \rightarrow D_{SJ}^*(2317) \gamma$ then
 - $D_{SJ}^*(2317)$ narrow, $D_s^*(2112)$ wide
- If $D_{SJ}(2458) \rightarrow D_{SJ}^*(2112) \pi^0$ then
 - $D_{SJ}^*(2317)$ wide, $D_s^*(2112)$ narrow
- Need to fit full distributions to disentangle



Channel Likelihood Fit

- Variant on maximum likelihood.
- Model the competing decay channels, bkgd
 - $D_s(2458) \rightarrow D_s(2317) \gamma$
 - $D_s(2458) \rightarrow D_s^*(2112) \pi^0$
 - $D_s(2317) + (\gamma)$
 - $D_s^*(2112) + (\pi^0)$
- For each event, assign likelihoods to hypotheses.
- A posteriori, assign weights to events.
- Convenient way to plot results.



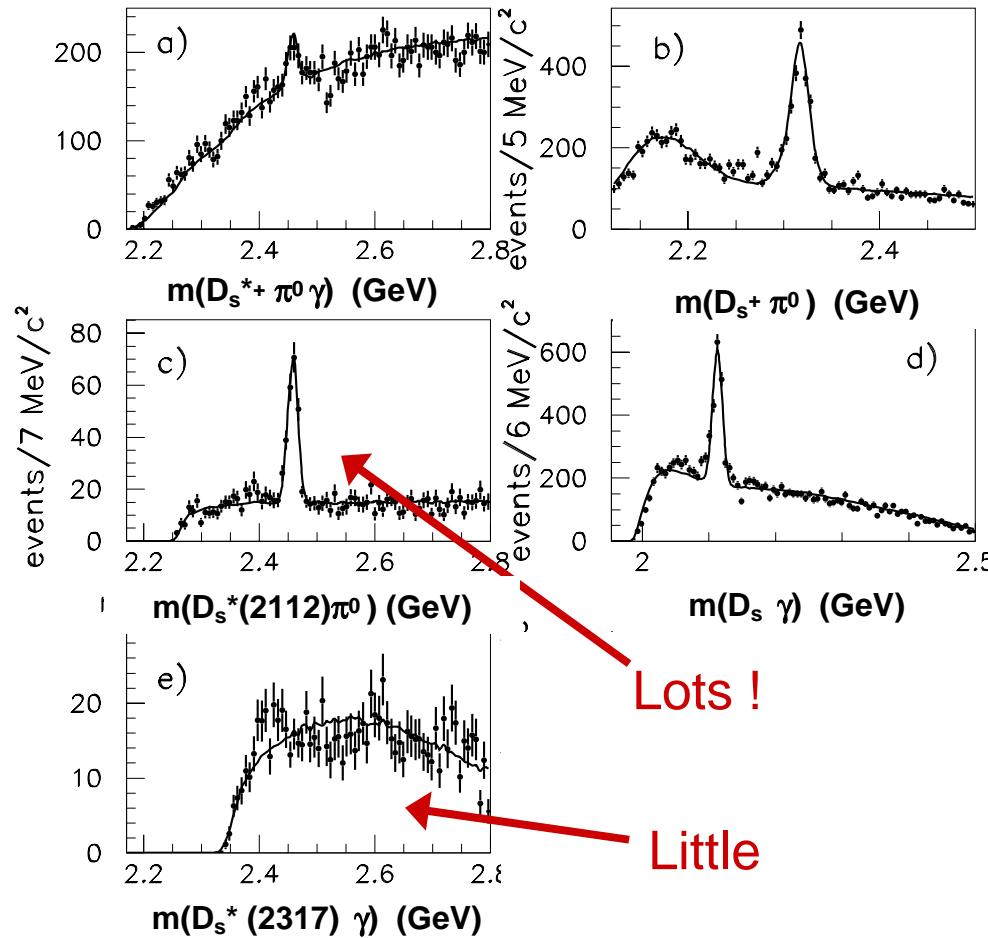
Separate Contributions to $D_s \pi^0 \gamma$ Events

BaBar Preliminary

$D_s \pi^0 \gamma$

$D_s^* \pi^0$
weighted

$D_s(2317) \gamma$
weighted



$D_s \pi^0$
projection

$D_s \gamma$
projection



D_s γ structure is narrow

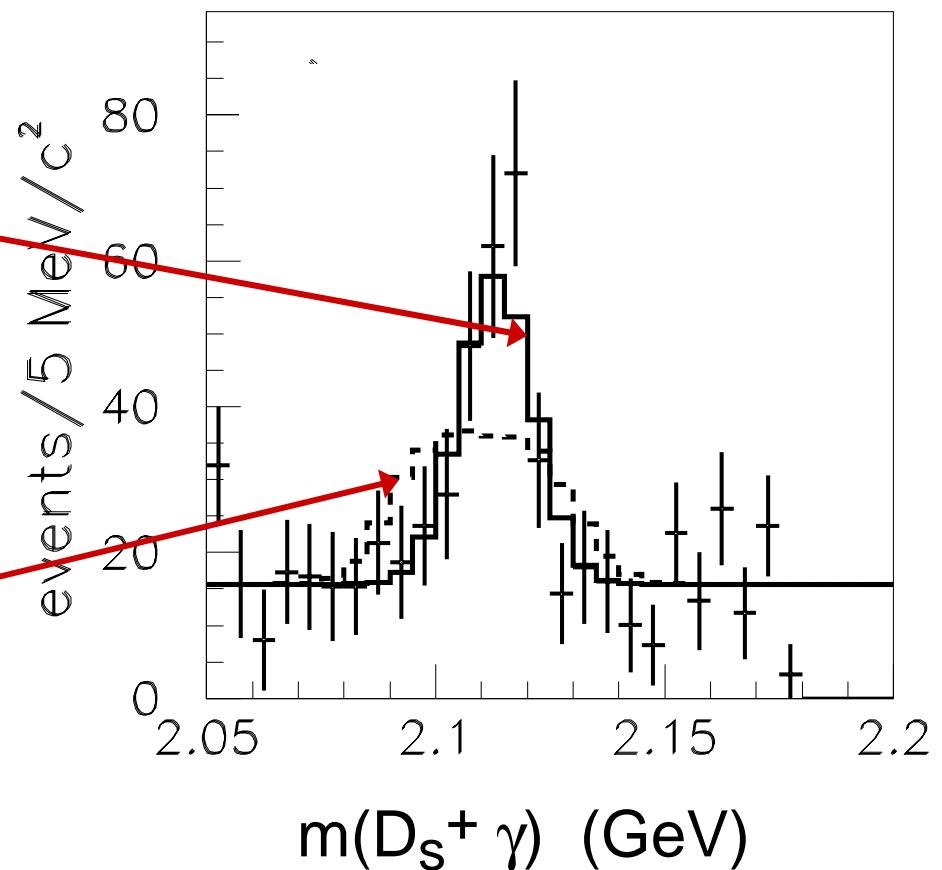
BaBar Preliminary

MC assuming

$D_s(2458) \rightarrow D_s^*(2112) \pi^0$

MC assuming

$D_s(2458) \rightarrow D_s(2317) \gamma$





$D_s \pi^0$ structure is broad

BaBar Preliminary

MC assuming

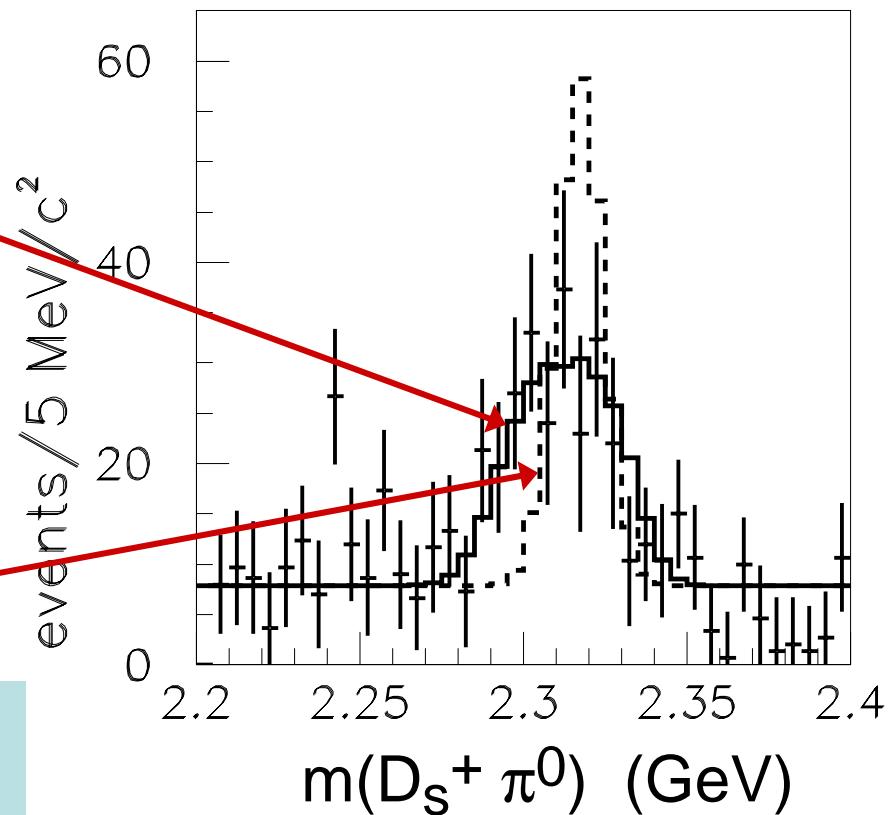
$D_s(2458) \rightarrow D_s^*(2112) \pi^0$

MC assuming

$D_s(2458) \rightarrow D_s(2317) \gamma$

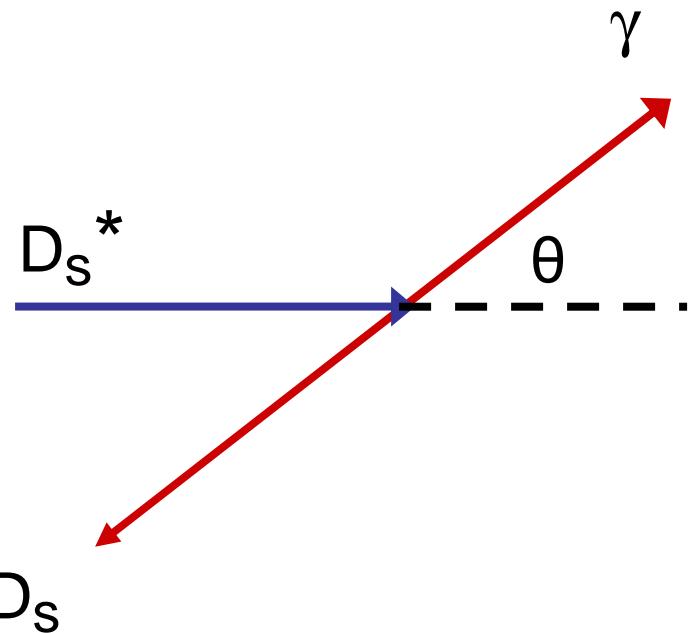
Conclude: decay is

$D_s(2458) \rightarrow D_s^*(2112) \pi^0$



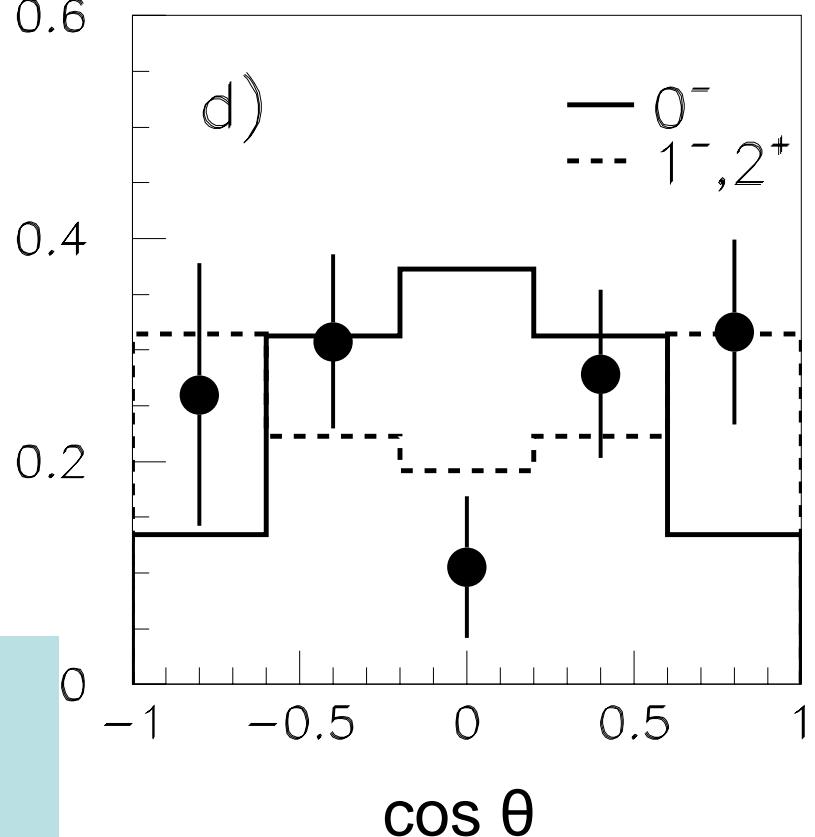


Spin of Ds(2458)



0 - disfavored, 1 - ok, 2 + ok;

1 +, 2 -, ... can't say anything





BaBar's Quantitative Results for $D_s(2458)$

- $D_{sJ}^+(2458) \rightarrow D_s^{*+}(2112)\pi^0$: 174 ± 22 evts
- $D_{sJ}^+(2458) \rightarrow D_{sJ}^{*+}(2317)\gamma$: 0 ± 19 evts
- $m = 2458.0 \pm 1.0 \pm 1.0$ MeV; $\sigma = 8.5 \pm 1.0$ MeV
Belle $2456.5 \pm 1.3 \pm 1.1$ MeV *CLEO* $2463.6 \pm 1.7 \pm 1.0$ MeV
- $m = 2317.3 \pm 0.4 \pm 0.8$ MeV;
Belle $2317.2 \pm 1.3 \pm 1.1$ MeV *CLEO* $2318.5 \pm 1.2 \pm 1.0$ MeV

BaBar Preliminary



BaBar rate ratios

BaBar Preliminary

$$\frac{\sigma(D_{sJ}(2458)^+) \mathcal{B}(D_{sJ}(2458)^+ \rightarrow D_s^*(2112)^+ \pi^0)}{\sigma(D_{sJ}^*(2317)^+) \mathcal{B}(D_{sJ}^*(2317)^+ \rightarrow D_s^+ \pi^0)}$$

$$= 0.23 \pm 0.03 \text{ (stat.)} \pm 0.03 \text{ (syst.)}$$

Belle 0.26 ± 0.08 ; *CLEO* 0.44 ± 0.11

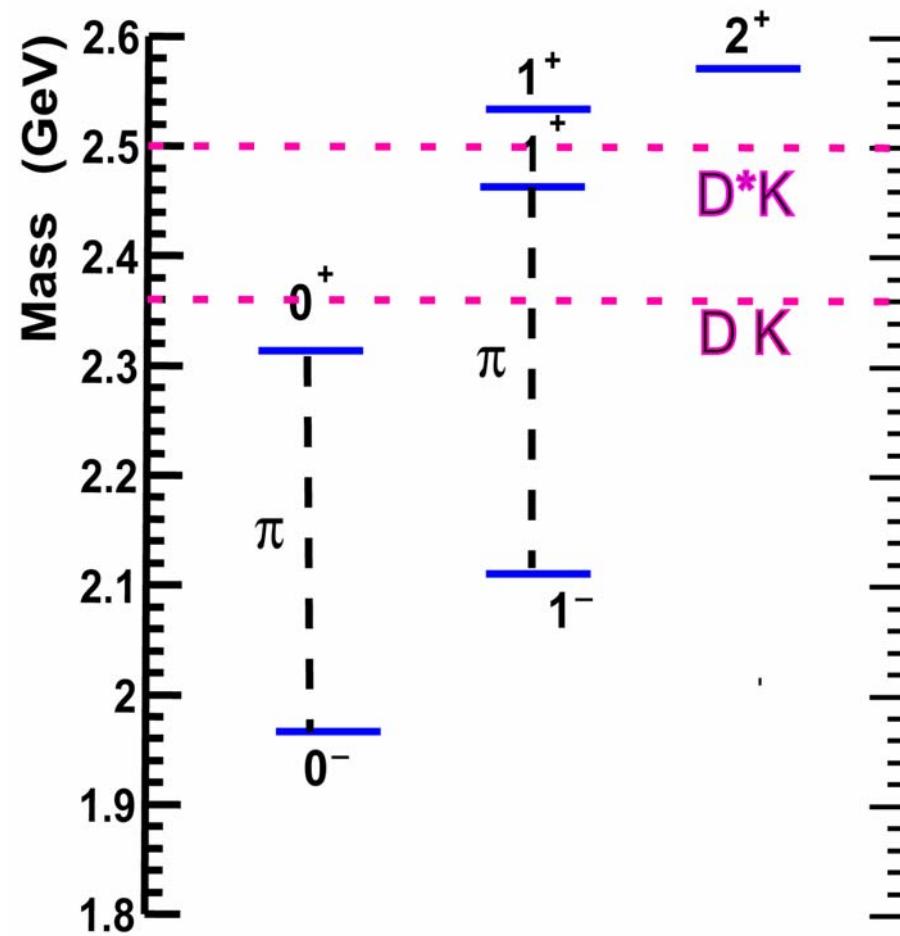
$$\frac{\mathcal{B}(D_{sJ}(2458)^+ \rightarrow D_{sJ}^*(2317)^+ \gamma)}{\mathcal{B}(D_{sJ}(2458)^+ \rightarrow D_s^*(2112)^+ \pi^0)} < 0.2$$



Consistent Picture of 2317 and 2458

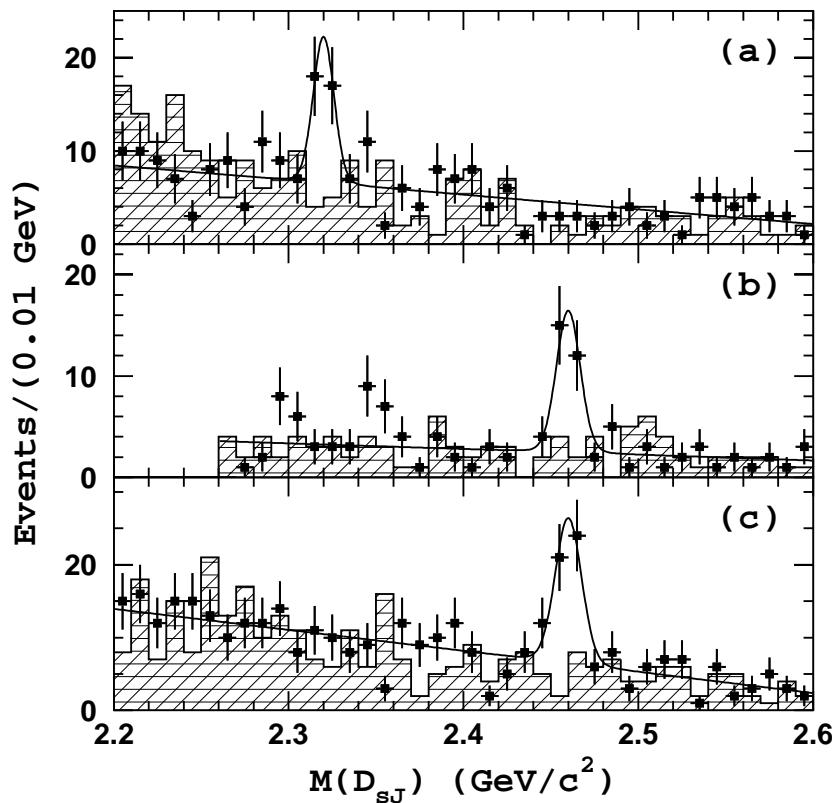
Isospin conserving
decays to DK and
D*K unavailable

Isospin violation:
View as $\eta - \pi$ mixing.





Belle: Exclusive B Decays



$B \rightarrow D D_{S J}^*(2317),$

$D_{S J}^*(2317) \rightarrow D s \pi 0$

$B \rightarrow D D_{S J}(2458),$

$D_{S J}(2458) \rightarrow D s^*(2112) \pi 0$

$B \rightarrow D D_{S J}(2458),$

$D_{S J}(2458) \rightarrow D s \gamma$



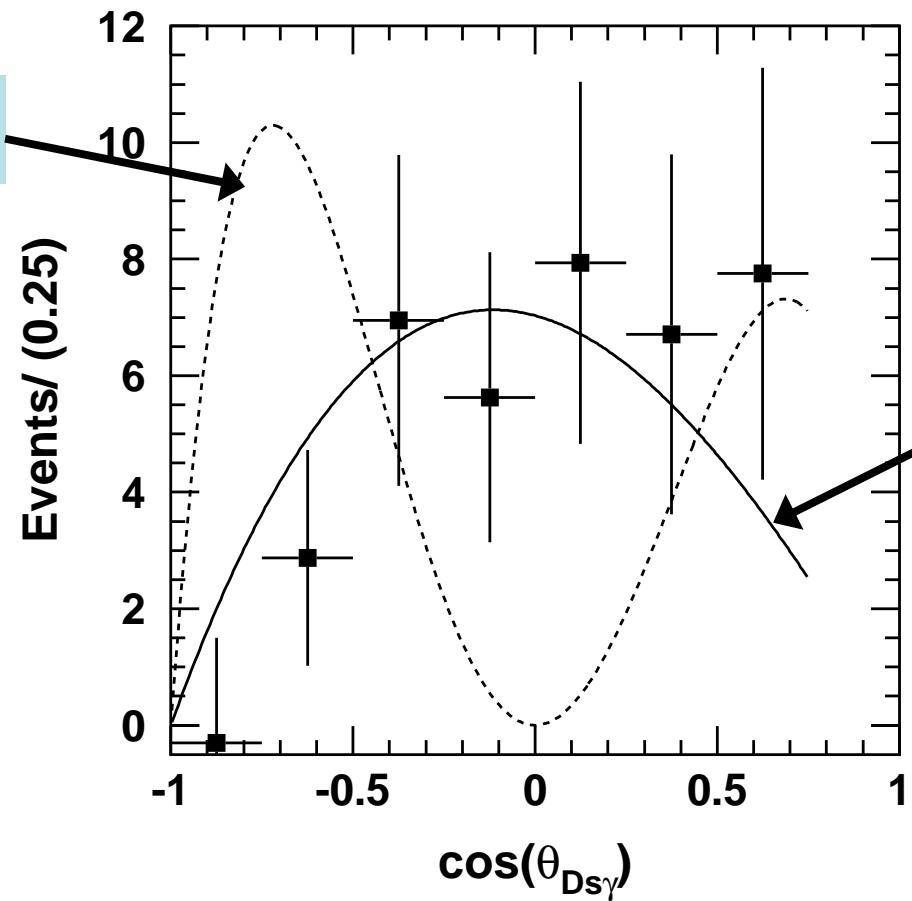
Belle: $B \rightarrow D\bar{D}_{SJ}(2458)$, $D_{SJ}(2458) \rightarrow D_s \gamma$

Spin-0
forbidden

Spin-2

Belle
– hep-ex/0308019

Spin-1





Current Picture Challenges Experiment and Theory

Can any potential model describe the spectra?

